Drought and Streamflow Variability for the Past 300 Years, Northern Montana to the Southern NWT

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PARC

C-CIARN
Canadian Climate Impacts and Adaptation Research Network

Climate Change and Water Resources
Winnipeg, MB, June 16-17, 2003


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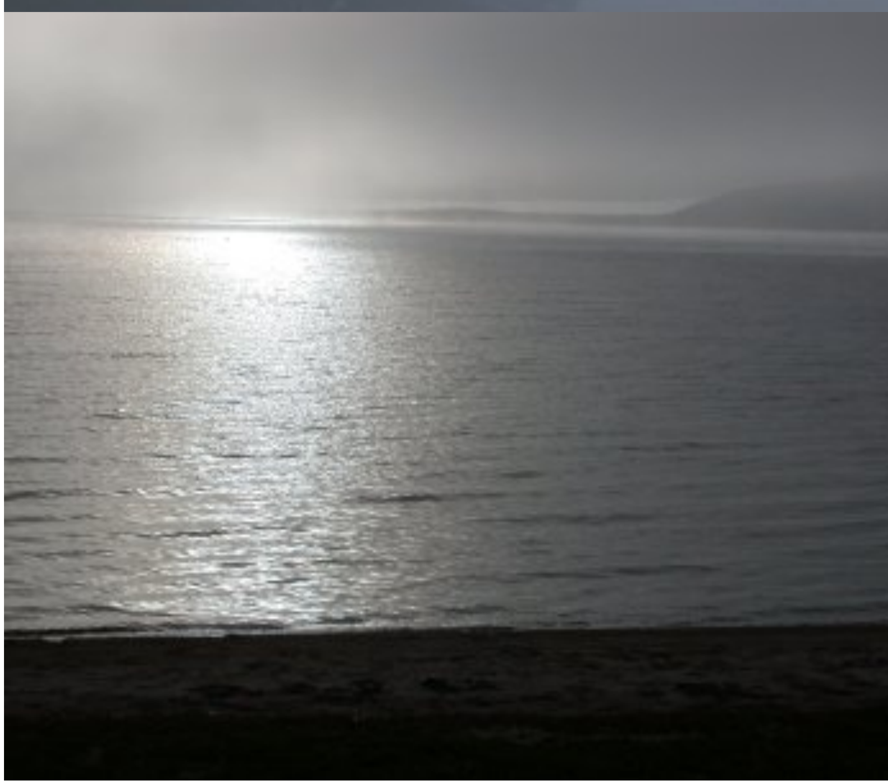





Paleoenvironmental Records for Climate Change Impacts and Adaptation

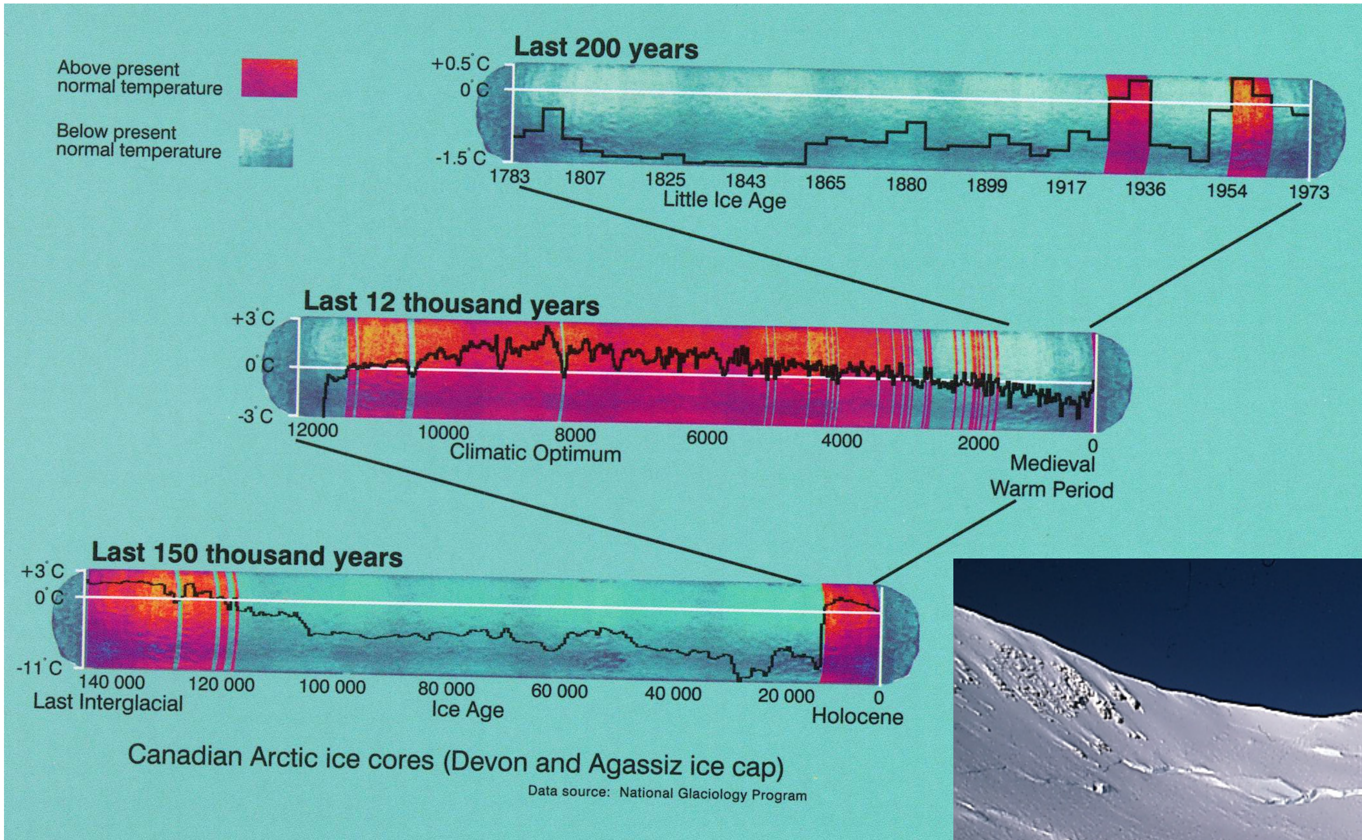
PARC

C-CIARN
Canadian Climate Impacts and Adaptation Research Network

PARC, University of Regina
March 21-22, 2003

see http://parc.ca/events

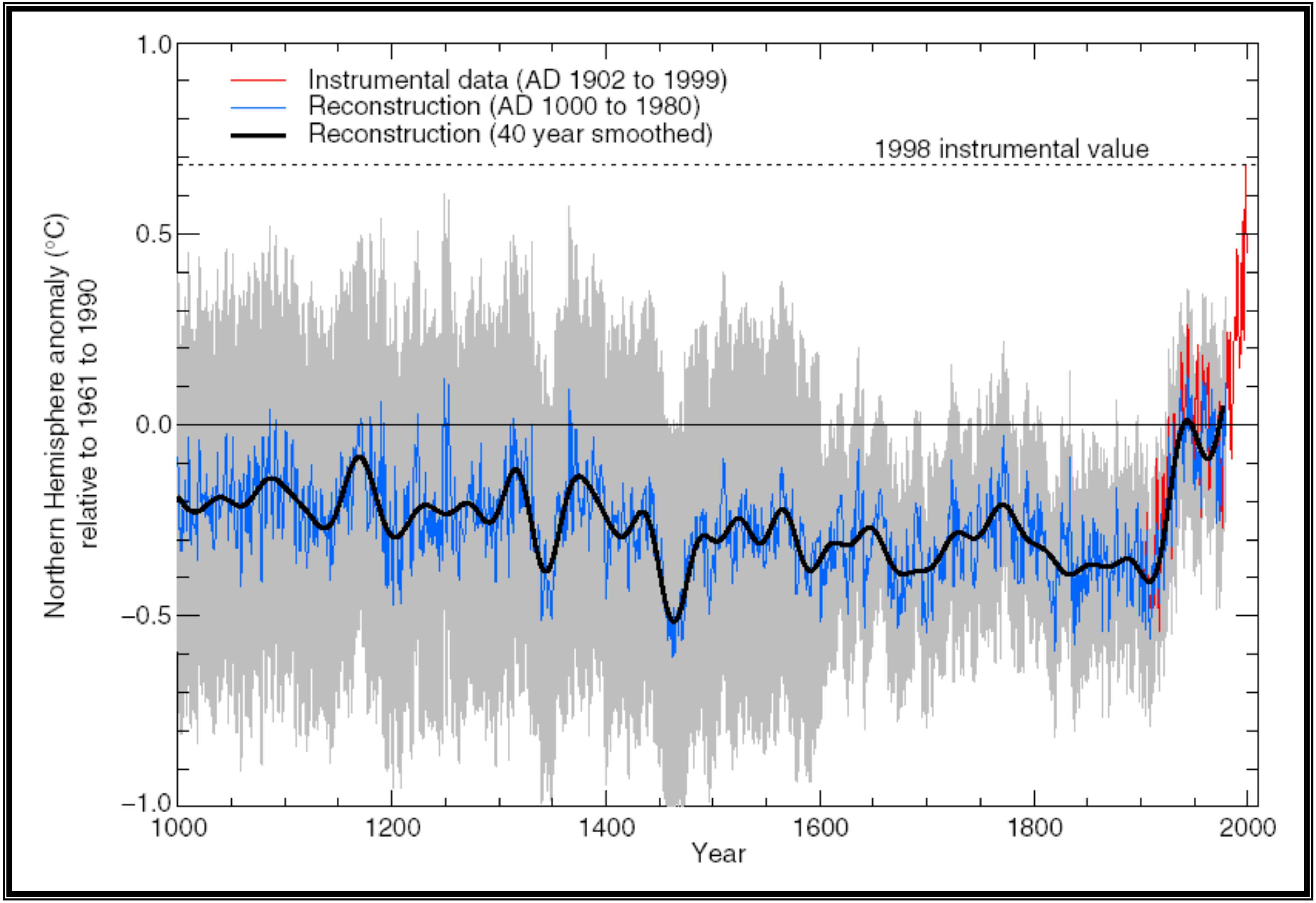
Climate is Always Changing



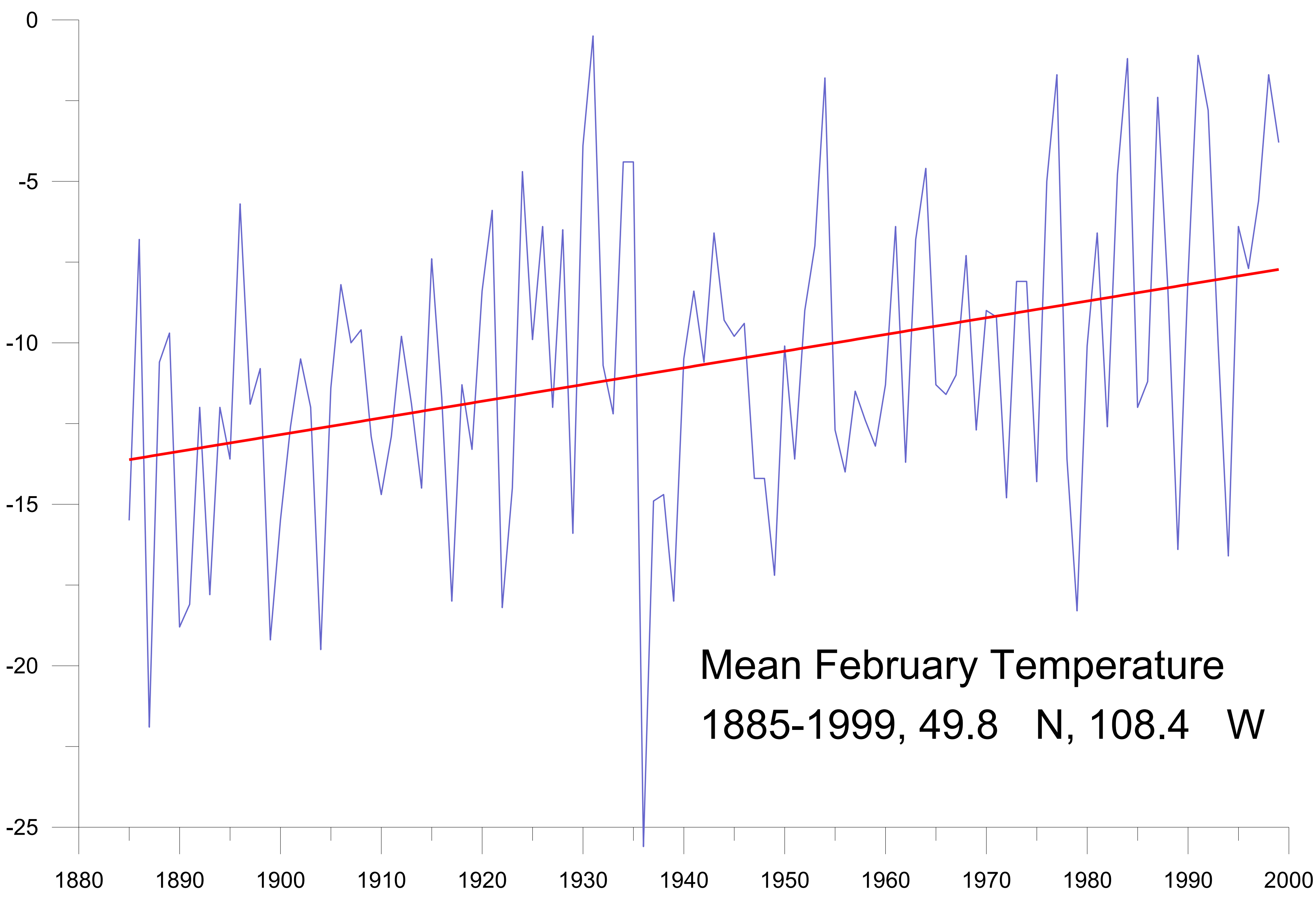
From GSC Misc. Report 71 (2001)

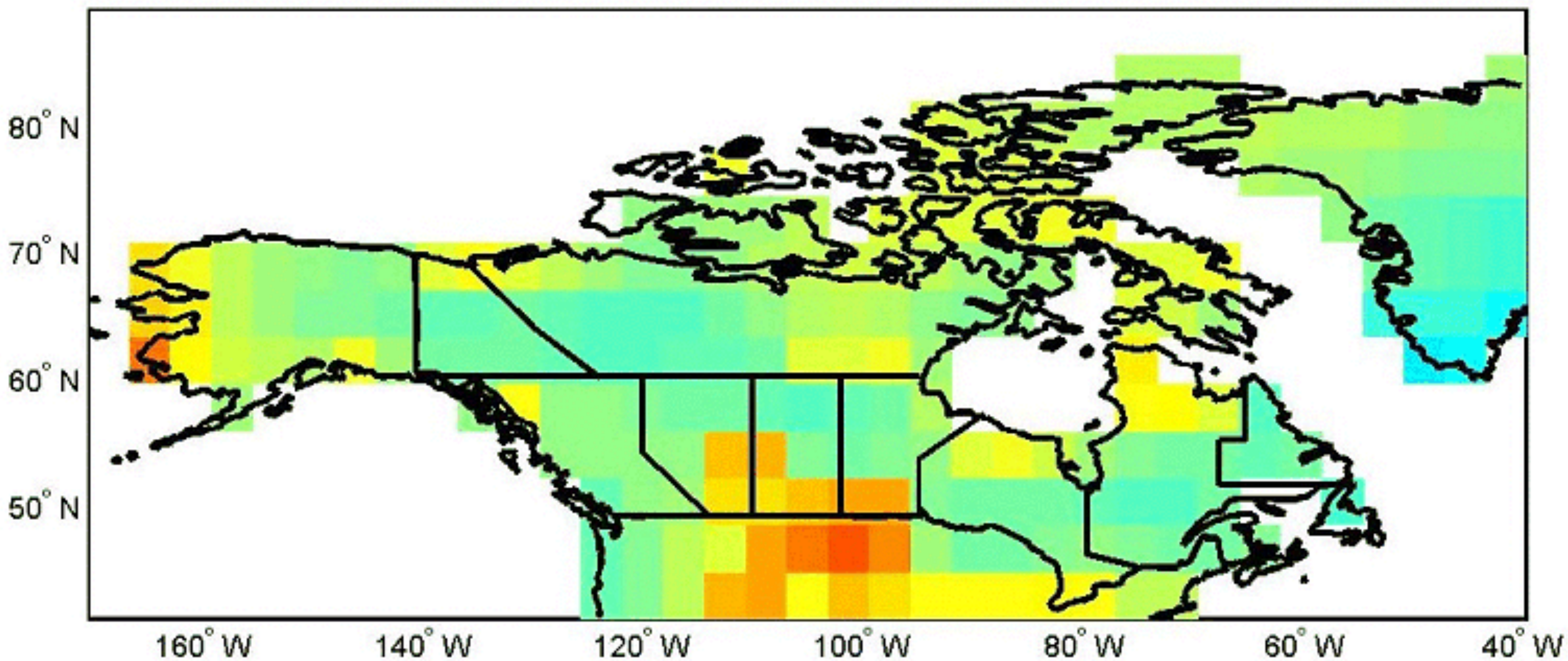
Ice cores, tree rings,
lakes and oceans sediments:
windows on the past

Northern Hemisphere (1000 years) temperature records

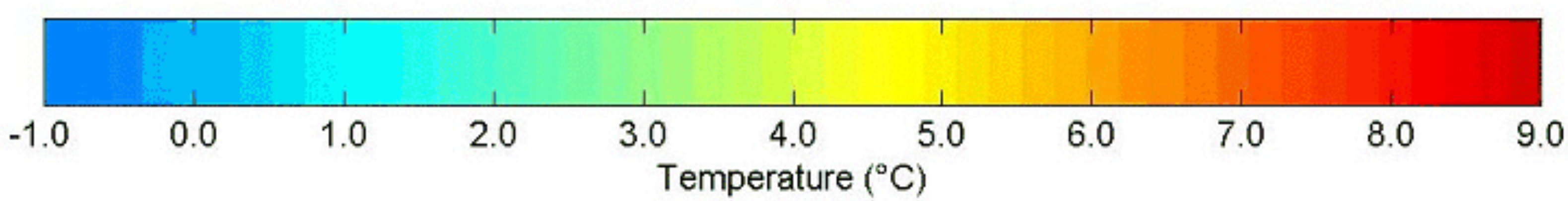


Mann, et al., 1999. Geophysical Res. Let. 26, 759-762.


0
-5
-10
-15
-20
-25
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Mean February Temperature
1885-1999, 49.8 N, 108.4 W



CGCM1, Mean Spring Temperature Change 2050



http://www.cics.uvic.ca/scenarios/index.cgi

Vulnerability Approach:
Understand the System of Concern

ISSUES

Engage stakeholders

↓ Those affected
Key decision makers

OBSERVATION

Assess current vulnerability

↓ Use experience to assess potential impacts and damages

MODELS

Future conditions

↓ Climate
Environment
Socioeconomic
Policy
} Scenarios

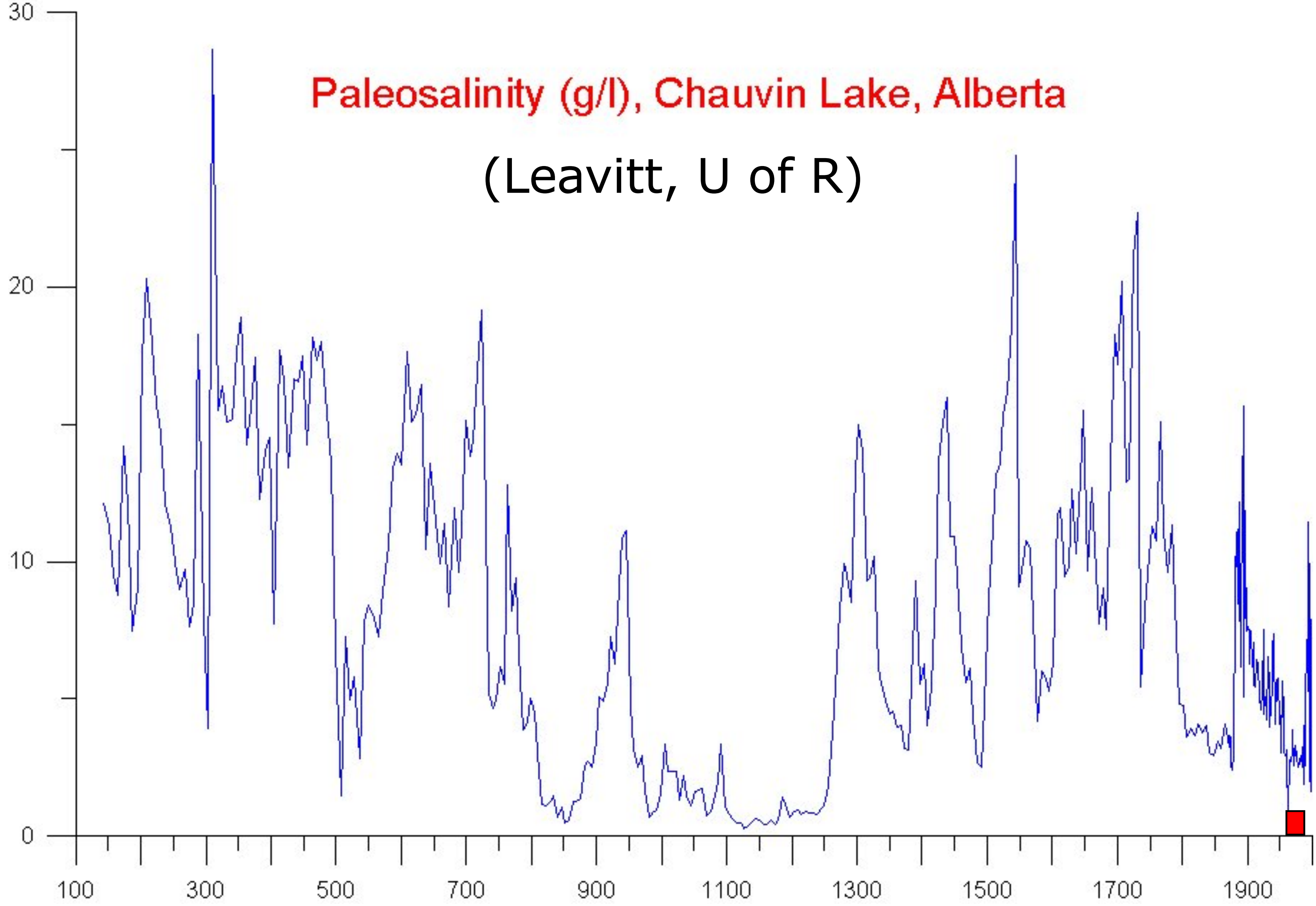
Information of Future Vulnerability / Adaptation Options

↓ Incorporate into risk management strategy

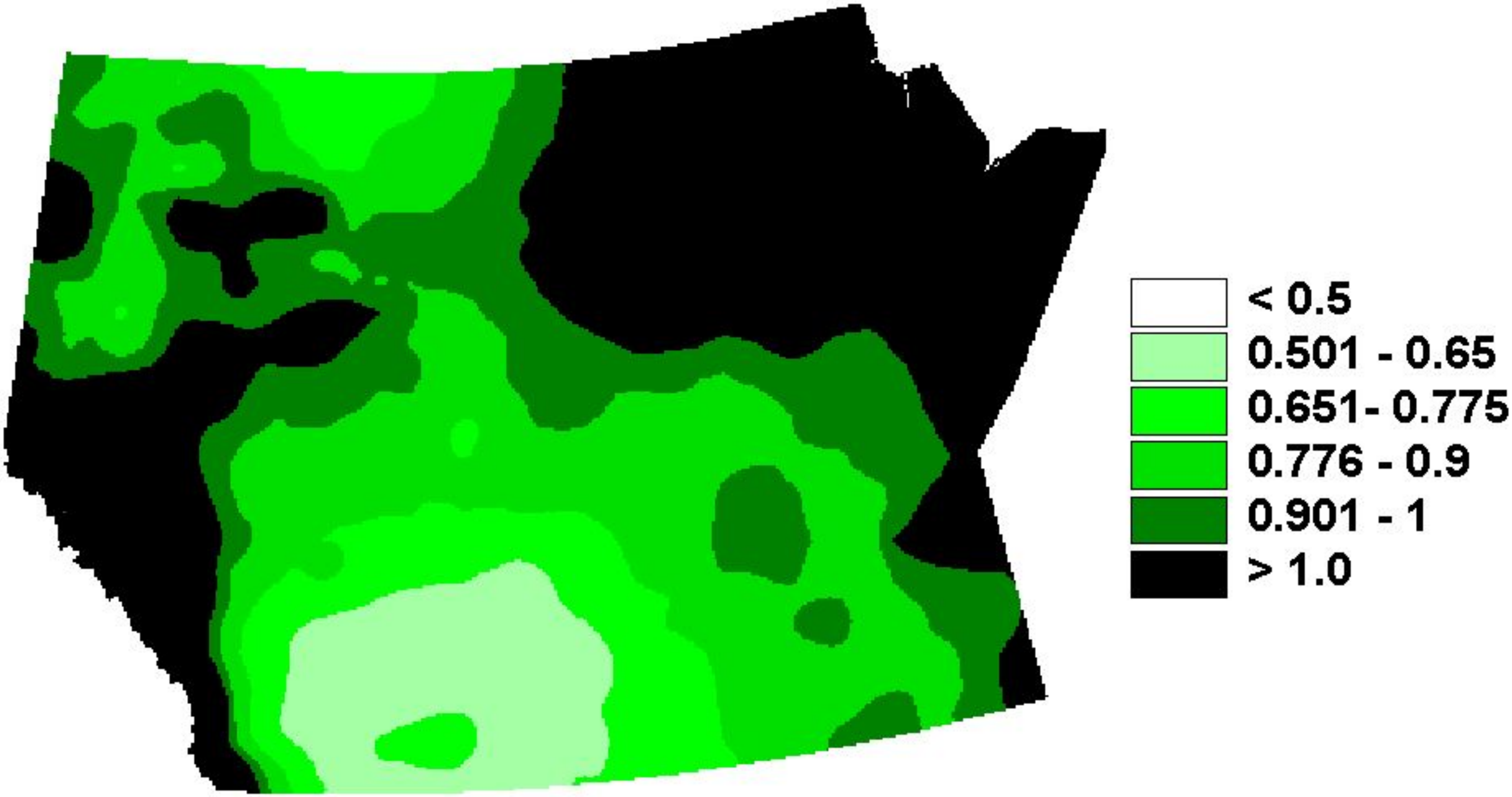
Decisions / implementation

Climatic Variability

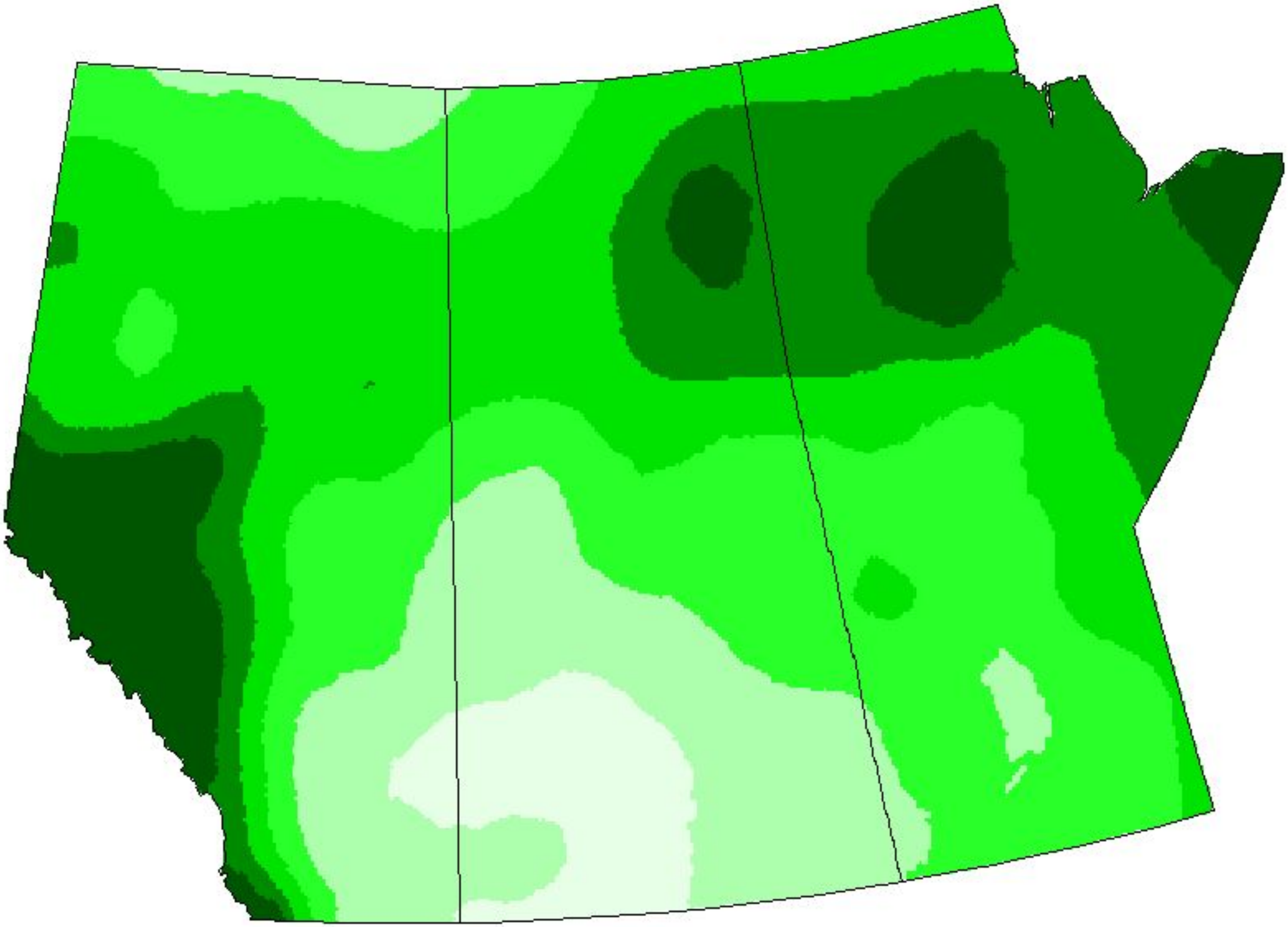
A projected increase in climate variability, including more frequent drought and major hydroclimatic events, is the most challenging climate change scenario. Social and biophysical systems respond to short-term climate variability and to extreme events long before they respond to gradual changes in mean conditions. More extreme climate anomalies are likely to exceed natural and engineering thresholds beyond which the impacts of climate are more severe.


Paleosalinity (g/l), Chauvin Lake, Alberta
(Leavitt, U of R)
30
20
10
0
100
300
500
700
900
1100
1300
1500
1700
1900

Aridity Index (P/PET), 1961-90



Aridity (P/PET), 2050s, CGCM2



IPCC Workshop on Changes in Extreme Weather and Climate Events: Workshop Report. 11 – 13 June, 2002, Beijing, China, 107 pp.

- document quantitatively the intensity, frequency and duration of a variety of extreme phenomena on a range of space and time scales in the climate of the past century;
- assess whether recent changes in the intensity, frequency and duration of extremes are unusual in the context of instrumental and proxy records;
- express climate changes in the form of scenarios that can be applied in impact research

IPCC Workshop on Changes in Extreme Weather and Climate Events: Workshop Report. 11 – 13 June, 2002, Beijing, China, 107 pp.

- more paleoclimatic records/analyses and proxy indicators of pre-instrumental extremes,
- palaeo circulation records for the 'recent' 1000-2000 years should be used to put recent trends and variations in circulation-related extremes in the context of a longer history of natural variations
- whether indices calculated from model data have realistic variability, and if so, how the behaviour of these indices changes in transient climate change simulations;
- the available palaeo records and to assess the information they contain on extremes;
- long coupled control simulations (1000 to as long as 10000 years in length) should be analysed for interannual, decadal and centennial variations in simulated extremes; and
- appropriate impacts-relevant indices of extremes that are computable from available observational data and global or regional climate model outputs

Paleo Data (Products)

raw proxy data

filtered data (signal)

paleoclimatic and paleo-environmental records

trends, variability, frequencies, probabilities

temporal analogues

climate change and impact scenarios

I&A

NSERC
CRSNG

Manitoba Hydro

Dendrohydology of the Western Interior

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Environment Canada

CANADIAN WATER NETWORK
RÉSEAU CANADIEN DE L'EAU

PARC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Trees as Natural Archives

$$R_t = A_t + C_t + \delta D1_t + \delta D2_t + E_t$$

R_t: Tree ring width in year t

A_t: Age/size related growth trend due to normal physiological processes

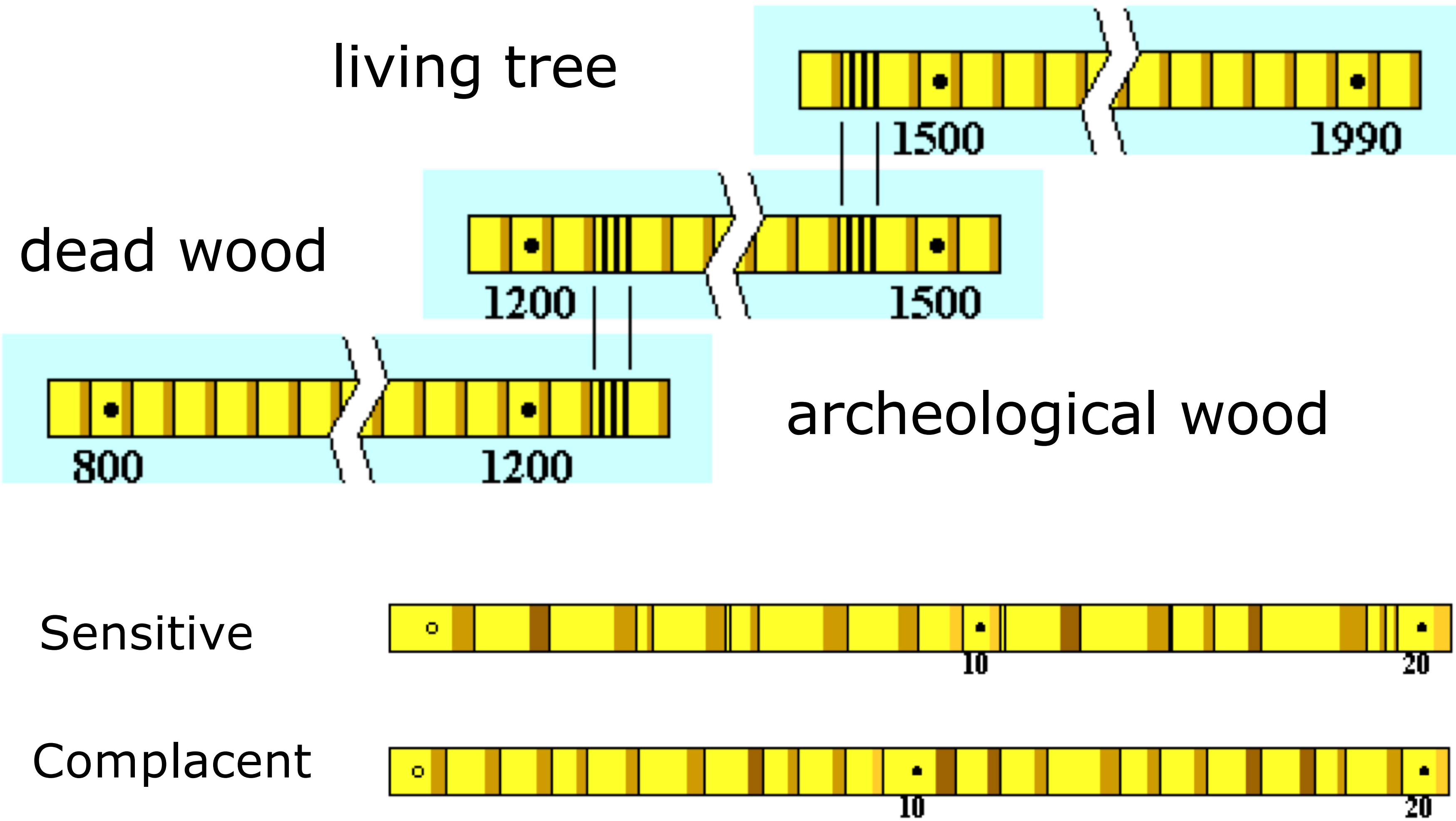
C_t: Climate that occurred during that year

$\delta D1_t$: Disturbance factors *within* the forest stand (for example, a blow down of trees)

$\delta D2_t$: Disturbance factors from *outside* the forest stand (for example, an insect outbreak that defoliates the trees, causing growth reduction)

E_t: Random processes which introduce Error

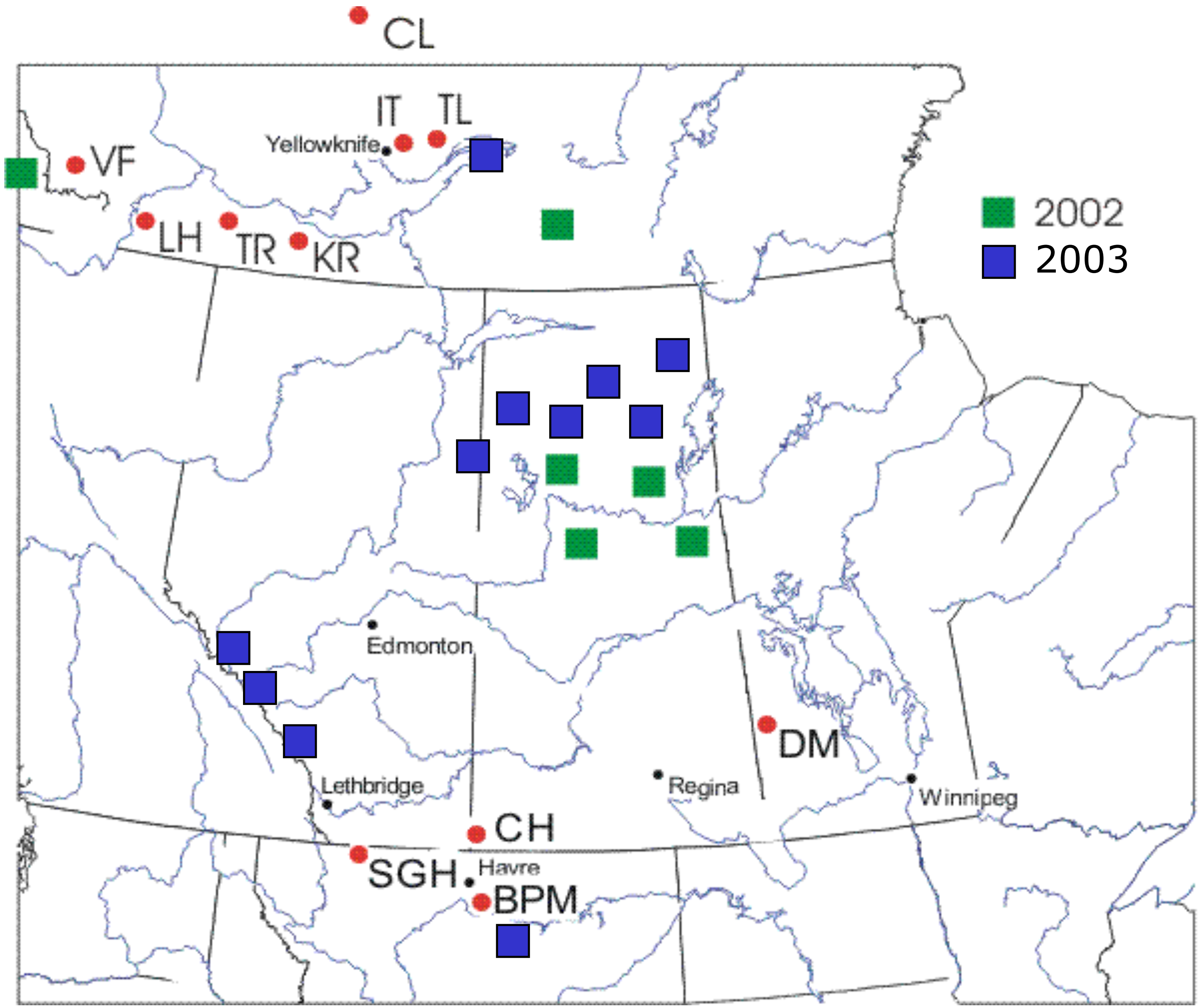
Crossdating

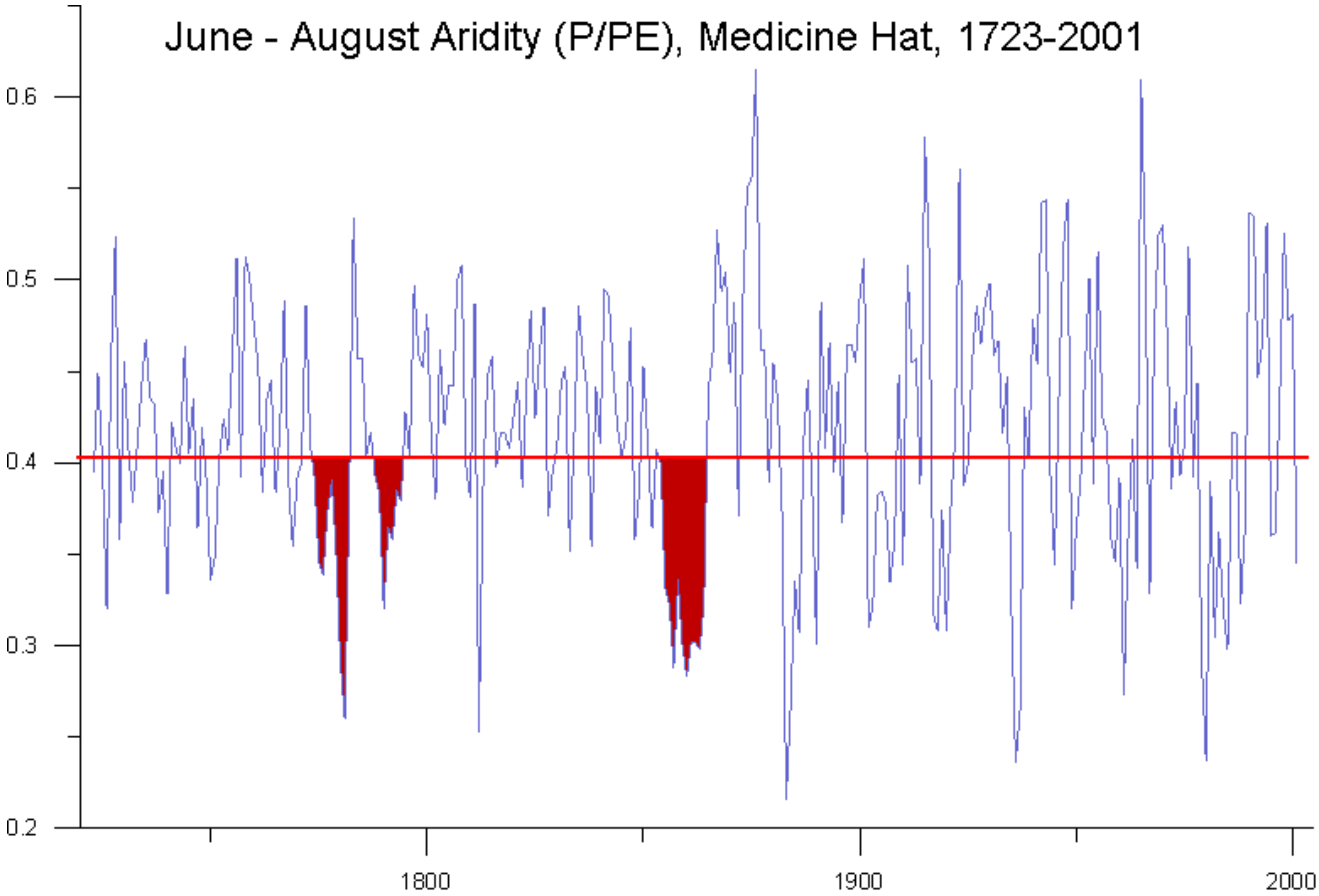


Extracting a Climate Signal

- Maximize the climate signal by replication
- Minimize ecological (disturbance) signals by removing samples or truncating series
- Remove the biological growth trend by fitting a growth curve
- Calculate dimensionless indices for each measurement to deal with different absolute growth rates
- Filter serial autocorrelation from time series to produce residual index chronologies

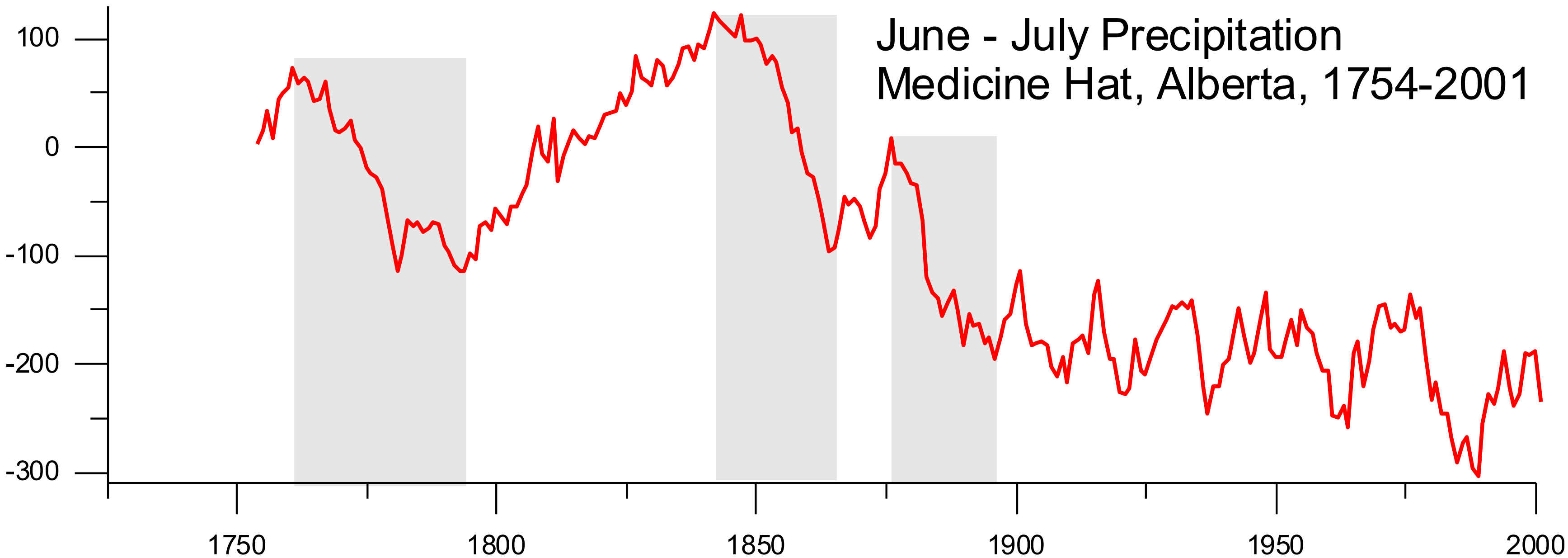
Tree-Ring Chronologies

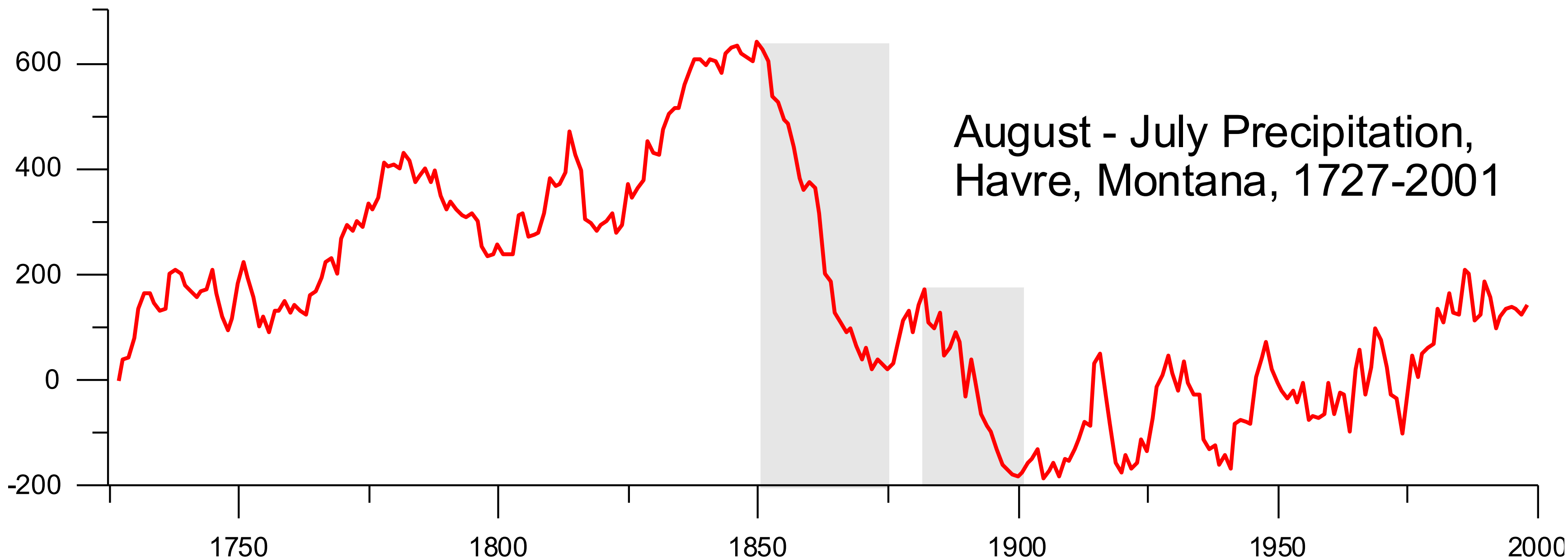


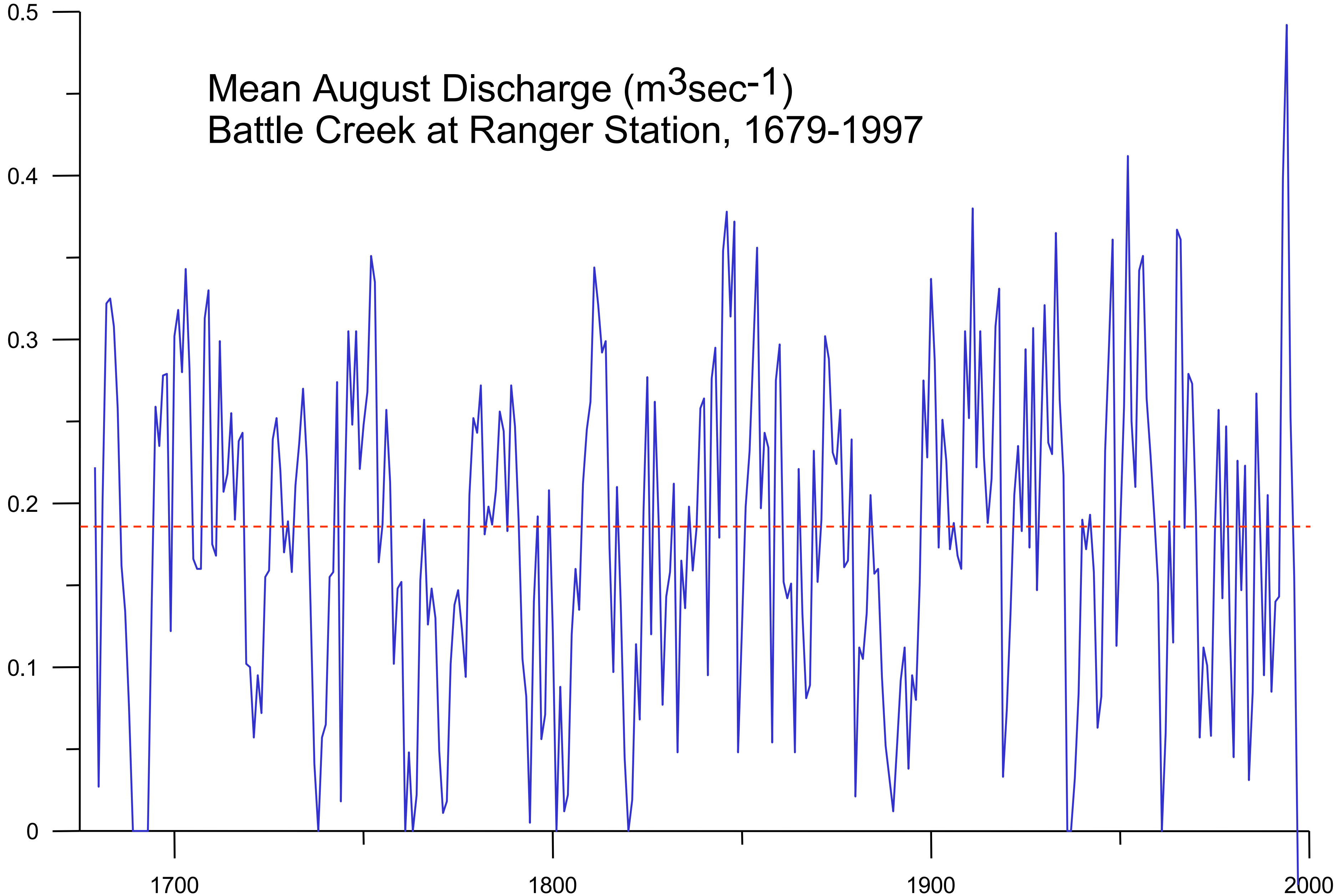


June - August Aridity (P/PE), Medicine Hat, 1723-2001
0.6
0.5
0.4
0.3
0.2
1800
1900
2000

Departures From Median Precipitaton







Mean August Discharge (m3sec-1)
Battle Creek at Ranger Station, 1679-1997
0.5
0.4
0.3
0.2
0.1
0
1700
1800
1900
2000

Mean August Q, Battle Creek at Ranger Station

Zero Flow	Lowest 10th Percentile		10th to 20th Percentile	
1689	1680	1894	1688	1868
1690	1737	1919	1721	1888
1691	1744	1938	1723	1891
1692	1764	1980	1739	1892
1738	1771	1984	1740	1896
1761	1772		1762	1920
1763	1794		1770	1939
1801	1803		1793	1944
1820	1804		1797	1945
1936	1819		1798	1962
1937	1821		1802	1971
1961	1880		1823	1974
1689	1889		1829	1985
1690	1890		1833	1990
			1849	
			1858	
			1864	
			1867	

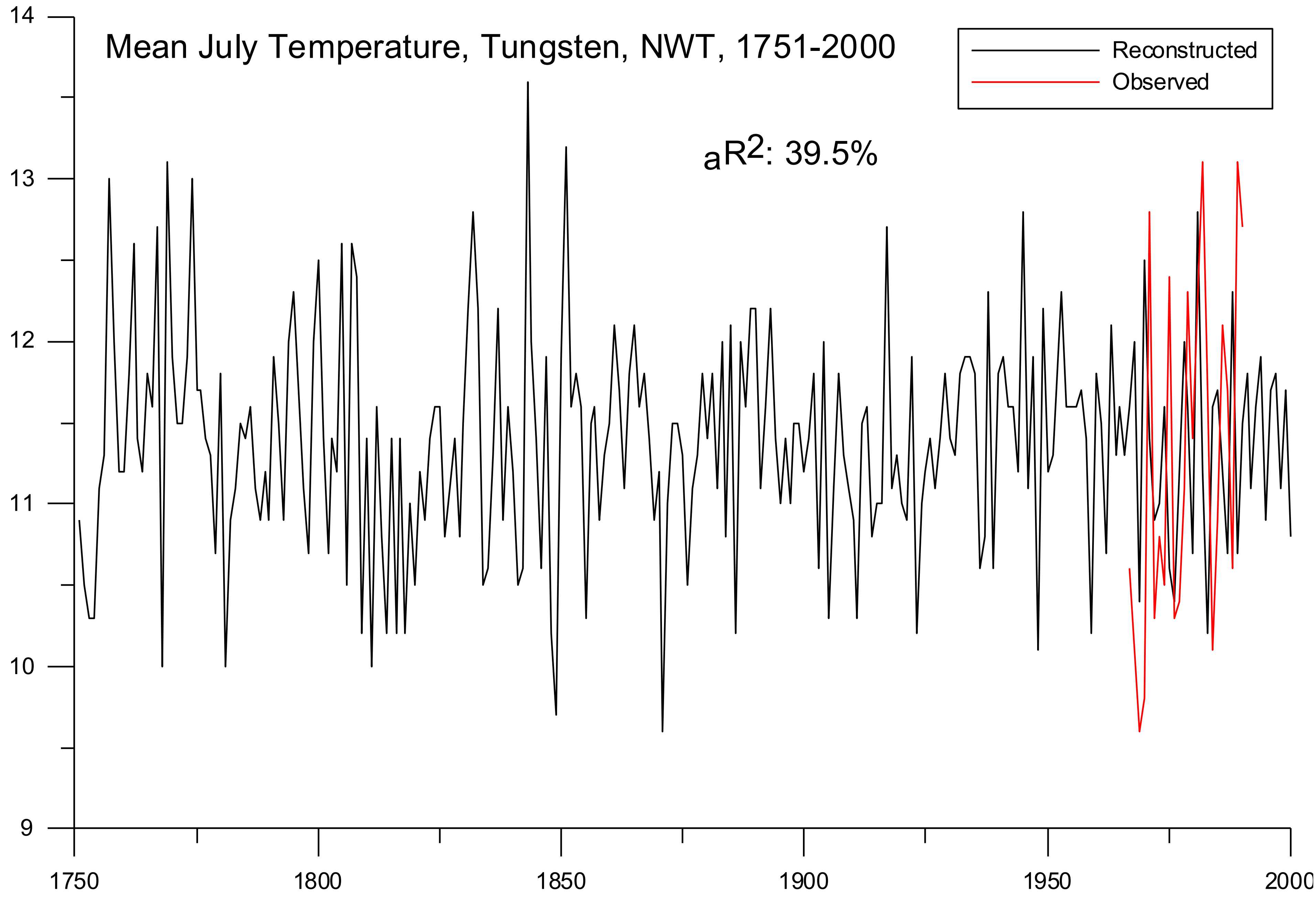
Near Outlook, Saskatchewan, May 2, 2002

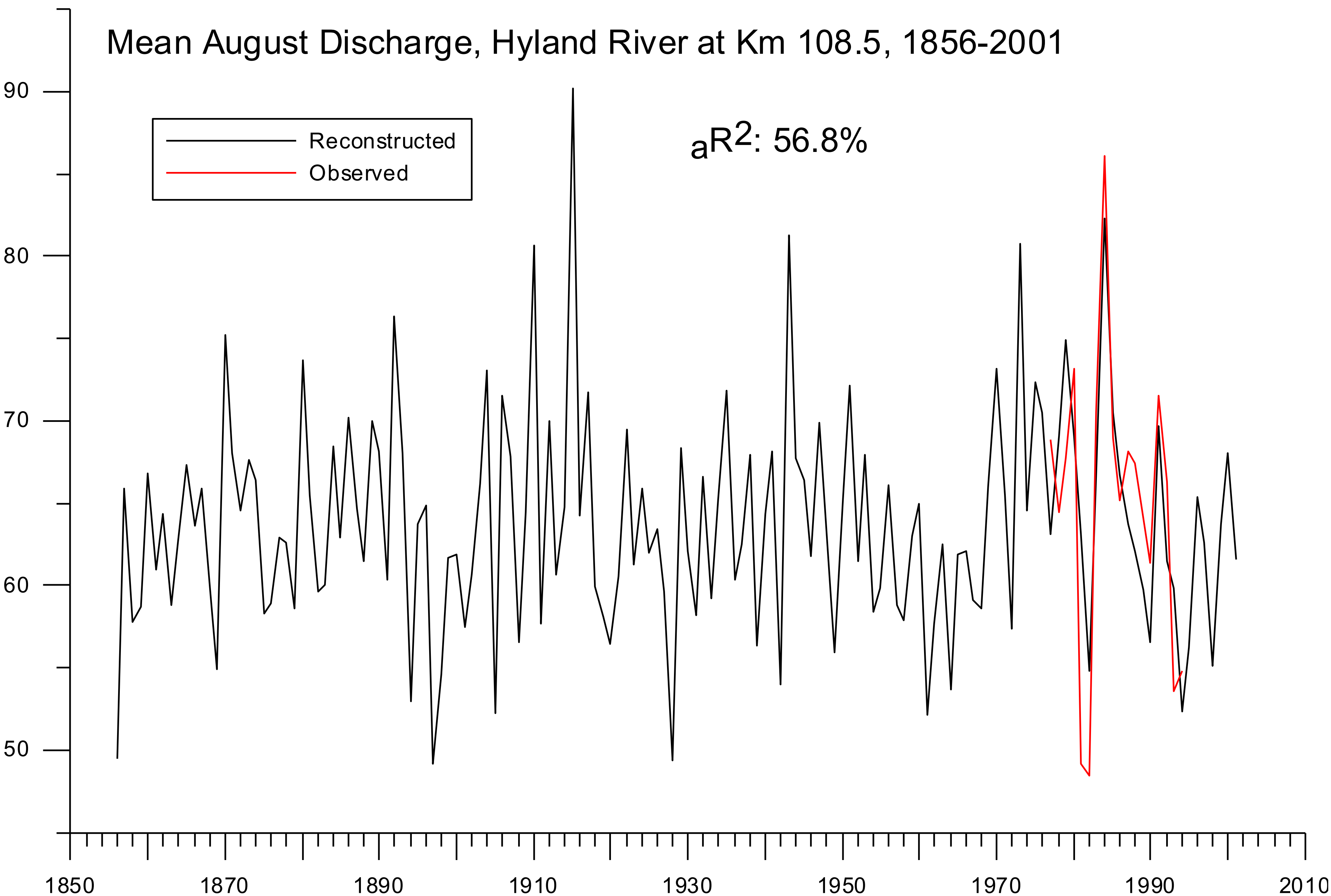
Tree-ring chronologies from the southern Mackenzie Mountains

Sites	Species
NNP – Nahanni National Park	PCGL - *Picea glauca* (white spruce),
VF – Virginia Falls	PICO – *Pinus contorta* (lodgepole pine)
SBM – Sunblood Mountain	PCMA – *Picea Mariana* (black spruce)
ML – Mirror Lake	
GR – Grizzly Ridge	
LKC – Lower Kaskula Creek	
UKC – Upper Kaskula Creek	
HV – Hyland Valley	
NRC – Nahanni Road Campground	
SC – Spruce Creek	

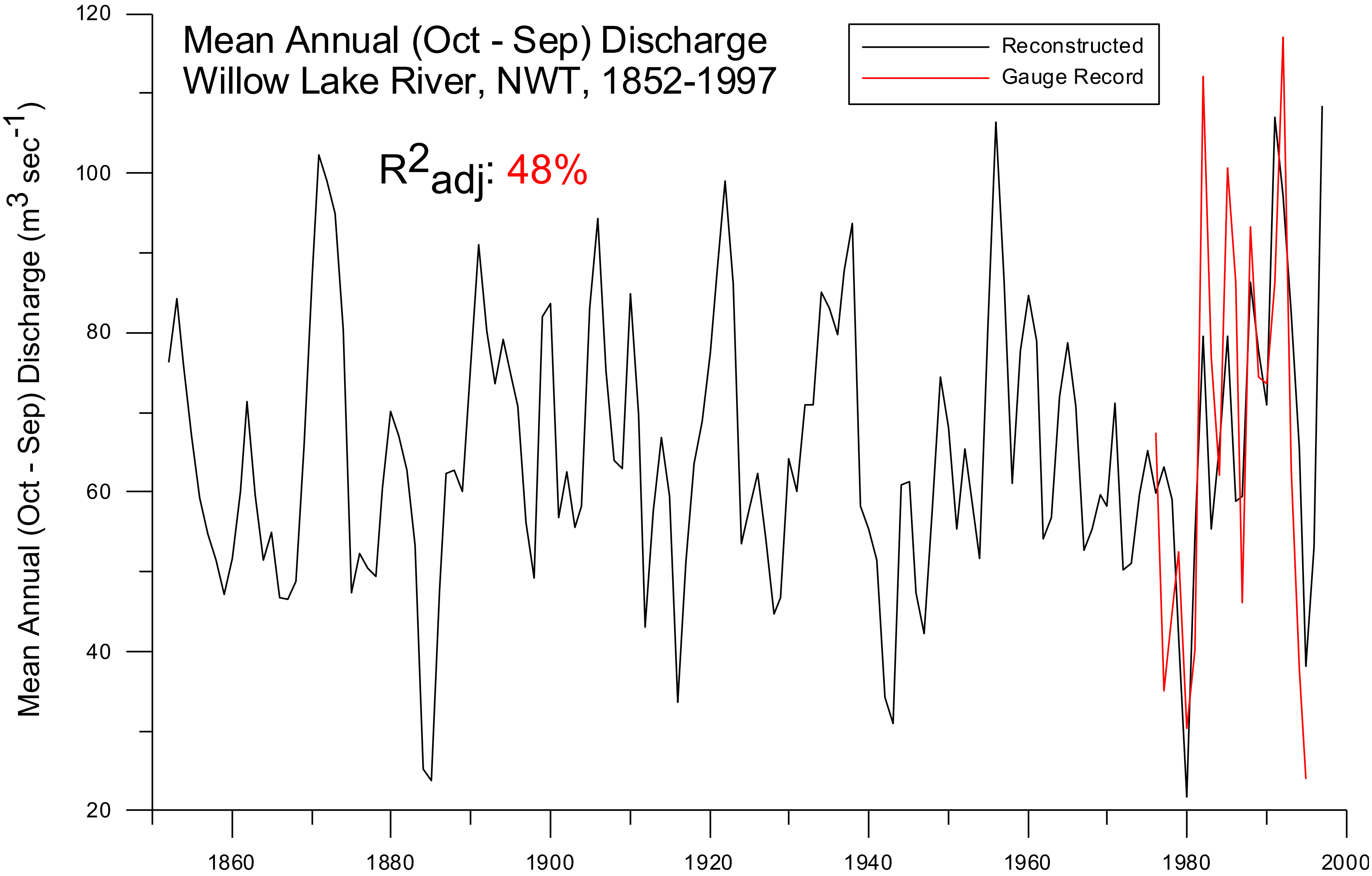
Tree-ring chronologies from the southern Mackenzie Mountains

	Number of series	Master dating series	Series intercorrelation	Average mean sensitivity
NNP_VF_PCGL	38	1665-2001	0.512	0.194
NNP_VF_PICO	30	1875-2001	0.451	0.254
NNP_SBM_PCGL	31	1699-2001	0.583	0.204
NNP_SBM_PICO	42	1765-2001	0.571	0.246
ML_GR_PCMA	27	1703-2001	0.584	0.202
ML_LKC_PCMA	19	1666-2001	0.542	0.160
ML_UKC_PCMA	32	1709-2001	0.564	0.190
HV_NRC_PICO	36	1838-2001	0.540	0.199
HV_SC_PICO	36	1853-2001	0.535	0.197

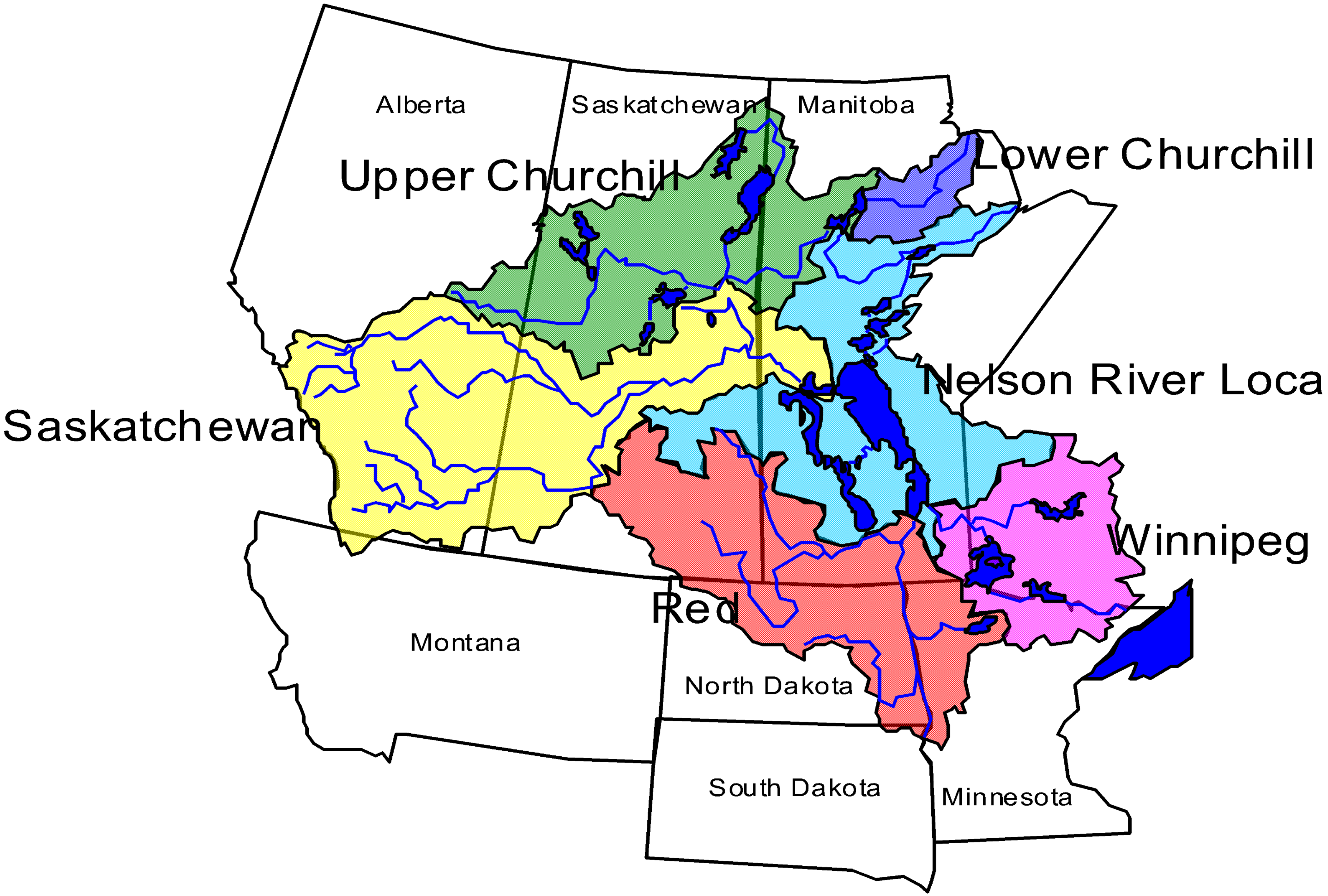

Mean July Temperature, Tungsten, NWT, 1751-2000
Reconstructed
Observed
aR2: 39.5%
14
13
12
11
10
9
1750
1800
1850
1900
1950
2000



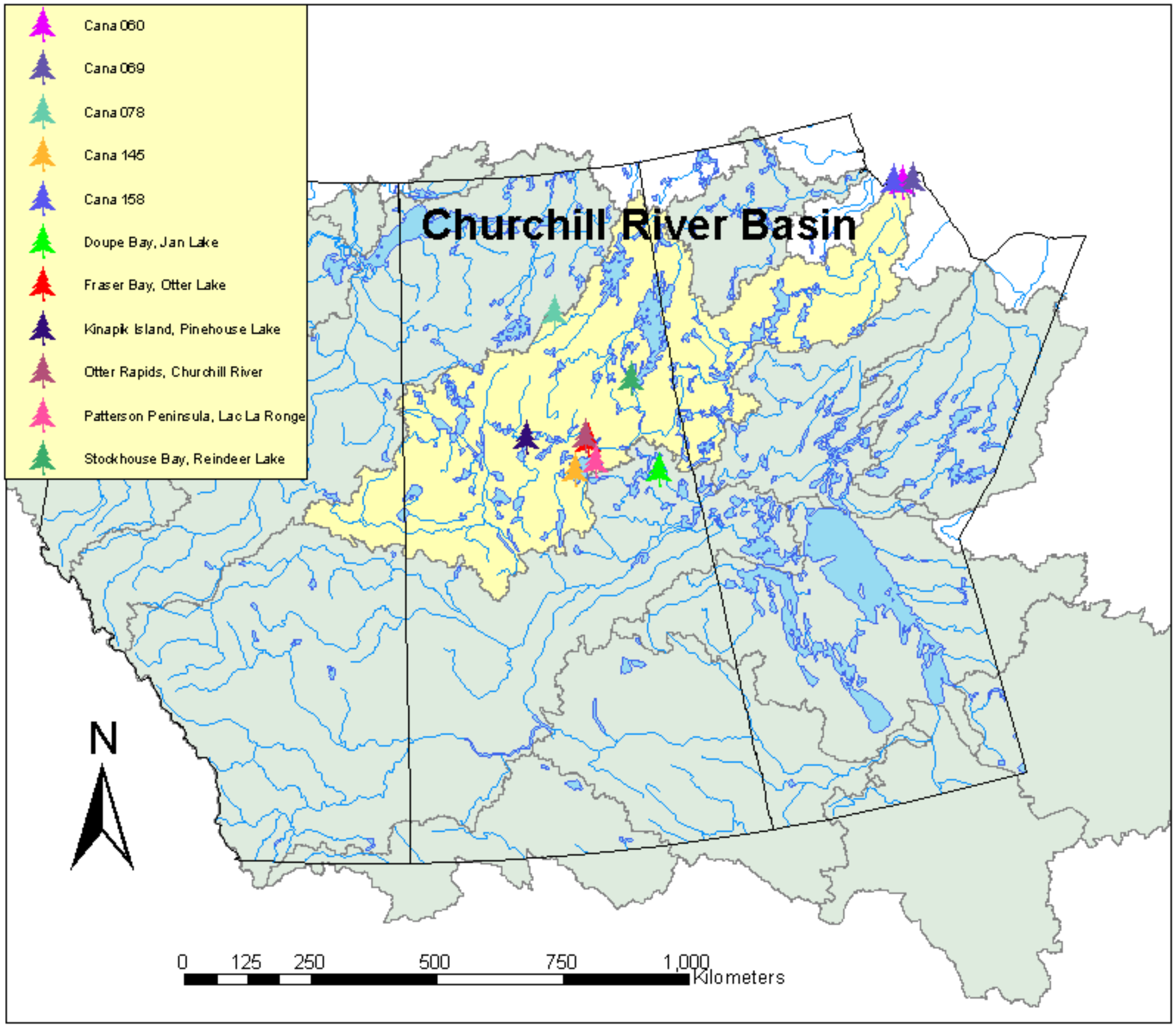
Mean August Discharge, Hyland River at Km 108.5, 1856-2001
Reconstructed
Observed
$_aR^2$: 56.8%
90
80
70
60
50
1850
1870
1890
1910
1930
1950
1970
1990
2010


Mean Annual (Oct - Sep) Discharge
Willow Lake River, NWT, 1852-1997
R^2_{adj}: 48%
Reconstructed
Gauge Record
Mean Annual (Oct - Sep) Discharge (m^3 sec^{-1})
120
100
80
60
40
20
1860
1880
1900
1920
1940
1960
1980
2000

Nelson - Churchill Drainage Basin



Dendrochronology Sites

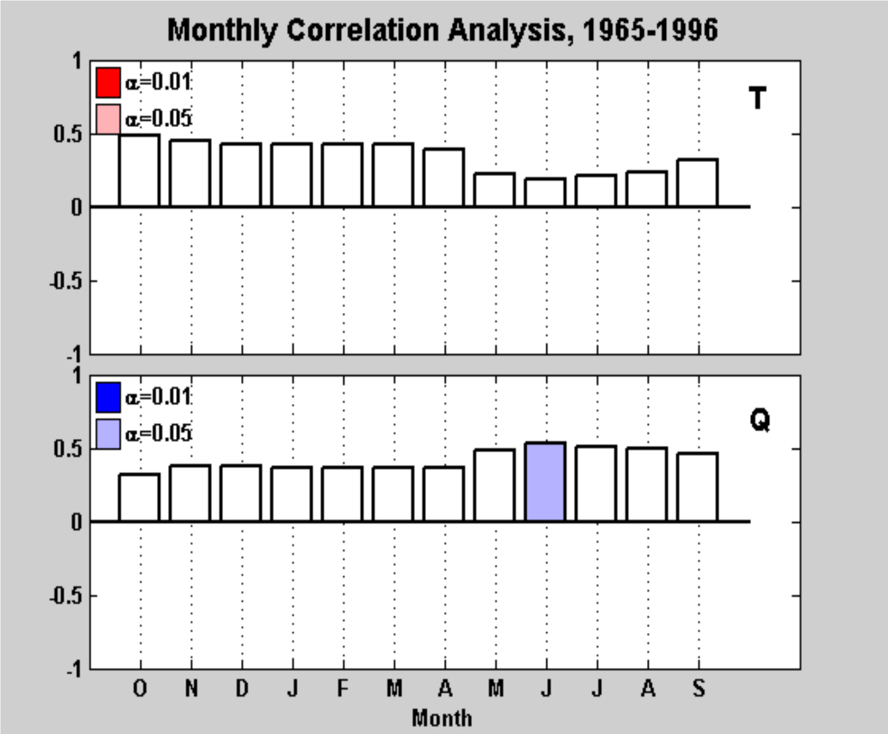


Chronology Statistics

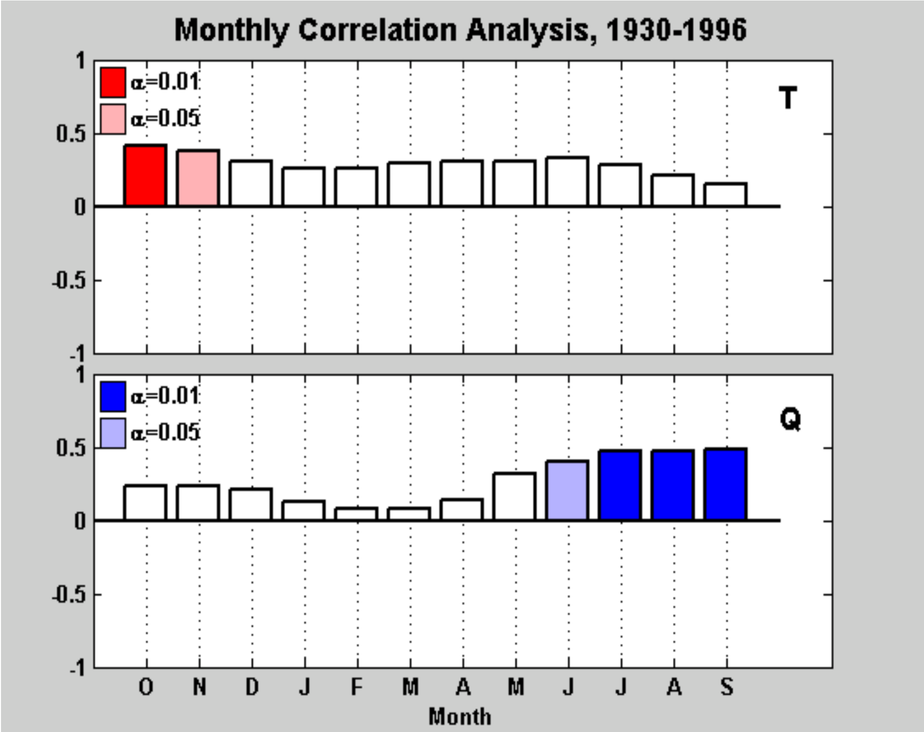
SITE	SPECIES	AGE (yrs)	SENSITIVITY/ PROBLEMS	CORRELATION
Doupe Bay	Picea *glauca*	163	.218 / 0	.603
Patterson Peninsula	Picea *marianna & Picea glauca*	175	.276 / 0	. 703
Fraser Bay	Picea *marianna & Picea glauca*	148	.222 / 0	.641
Otter Rapids	Picea *glauca*	123	.219 / 0	.671
Stockhouse Bay	Picea *Marianna*	167	.188 / 20	.515
Kinapik Island	Picea *glauca*	162	.249 / 0	.688

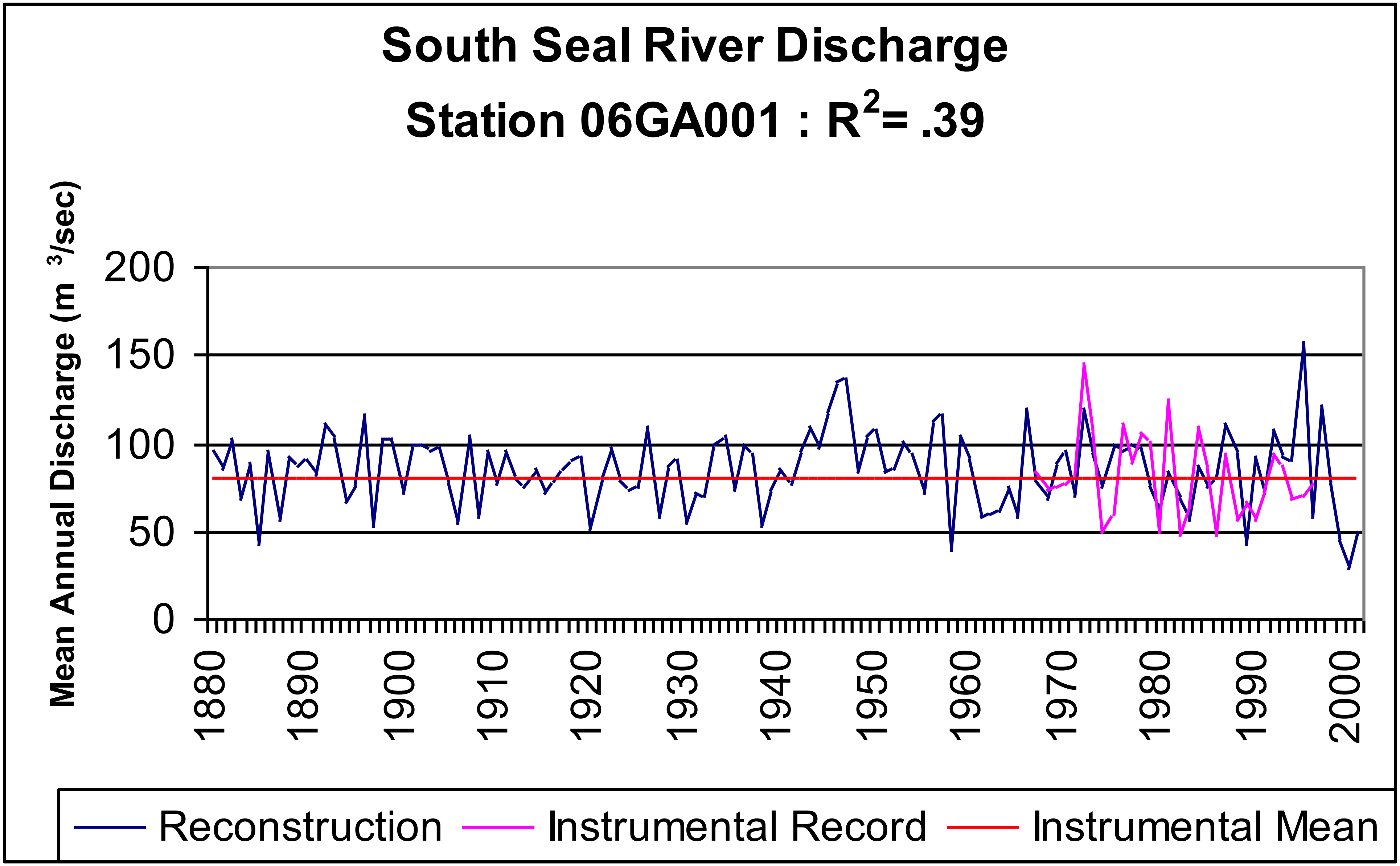
Monthly Response Functions for KI_{RES}

CR at Otter Rapids 06CD002



CR at Sandy Bay 06EA002




South Seal River Discharge
Station 06GA001 : R2= .39
Mean Annual Discharge (m 3/sec)
200
150
100
50
0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Reconstruction
Instrumental Record
Instrumental Mean

Antoine

Jennifer

Julie